

1

SILICON BASED SUBSTRATE WITH ENVIRONMENTAL/THERMAL BARRIER LAYER

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The invention described herein was made in the performance of work under NASA Contract No. NAS3-26385, and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, as amended (42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

The present invention relates to an article comprising a substrate containing silicon and a barrier layer which functions as a protective environmental/thermal barrier coating and, more particularly, a barrier layer which inhibits the formation of gaseous species of Si, particularly $\text{Si}(\text{OH})_x$ when the article is exposed to a high temperature, aqueous (water and/or steam) environment.

Ceramic materials containing silicon and metal alloys containing silicon have been proposed for structures used in high temperature applications as, for example, gas turbine engines, heat exchangers, internal combustion engines, and the like. A particular useful application for these materials is for use in gas turbine engines which operate at high temperatures in aqueous environments. It has been found that these silicon containing substrates can recede and lose mass as a result of a formation volatile Si species, particularly $\text{Si}(\text{OH})_x$ and SiO when exposed to high temperature, aqueous environments. For example, silicon carbide when exposed to a lean fuel environment of approximately 1 ATM pressure of water vapor at 1200° C. will exhibit weight loss and recession at a rate of approximately 6 mils per 1000 hrs. It is believed that the process involves oxidation of the silicon carbide to form silica on the surface of the silicon carbide followed by reaction of the silica with steam to form volatile species of silicon such as $\text{Si}(\text{OH})_x$. Naturally it would be highly desirable to provide a external barrier coating for silicon containing substrates which would inhibit the formation of volatile silicon species, $\text{Si}(\text{OH})_x$ and SiO , and thereby reduce recession and mass loss.

Accordingly, it is the principle object of the present invention to provide an article comprising a silicon containing substrate with a barrier layer which inhibits the formation of gaseous species of Si, particularly $\text{Si}(\text{OH})_x$, when the article is exposed to a high temperature, aqueous environment.

A second objective of this invention is to provide an article comprising a substrate with a barrier layer providing thermal protection, such layer closely matching the thermal expansion of the substrate.

It is a further object of the present invention to provide a method for producing an article as aforesaid.

SUMMARY OF THE INVENTION

The present invention relates to an article comprising a silicon containing substrate having a barrier layer on the substrate, wherein the barrier layer functions to both inhibit the formation of undesirable gaseous species of silicon when the article is exposed to a high temperature, aqueous environment and to provide thermal protection. By high temperatures is meant the temperature at which the Si in the substrate forms $\text{Si}(\text{OH})_x$ and/or SiO in an aqueous environment. By aqueous environment is meant a water and/or steam environment. The silicon containing composite is

2

preferably a ceramic or metal alloy containing silicon. The external barrier layer is characterized by a coefficient of thermal expansion which is within plus or minus 3.0 ppm per degree centigrade of the coefficient of expansion of the silicon containing substrate. The preferred barrier layer in accordance with the present invention is a barium aluminosilicate and, preferably, a barium-alkaline earth aluminosilicate wherein the alkaline earth metal is ideally strontium. In a preferred embodiment of the present invention the article can include one or more intermediate layers between the silicon based substrate and the barrier layer. The intermediate layer(s) serve(s) to provide enhanced adherence between the barrier layer and the substrate and/or to prevent reactions between the barrier layer and the substrate.

The invention further relates to a method for producing an article comprising a silicon containing substrate and a barrier layer which inhibits the formation of gaseous species of silicon and/or provides thermal protection when the article is exposed to a high temperature, aqueous environment as defined above.

Further objects and advantages of the present invention will appear hereinbelow from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing the stability of the barrier layer of the present invention with respect to recession and mass loss;

FIG. 2 is a photomicrograph through a sample of the barrier layer of the present invention on a silicon carbide substrate;

FIG. 3 is a photomicrograph of a sample of the barrier layer of the present invention applied to an intermediate layer on a silicon carbide substrate; and

FIG. 4 demonstrates the effect of three specimens of the barrier layer of the present invention on weight loss in high temperature, aqueous environments.

DETAILED DESCRIPTION

The present invention relates to an article comprising a silicon containing substrate and a barrier layer, wherein the barrier layer inhibits the formation of gaseous species of silicon when the article is exposed to a high temperature, aqueous environment. The invention also relates to a method for producing the aforesaid article. In addition, it should be appreciated that while the barrier is particularly directed to an environmental barrier layer, the barrier layer also functions as a thermal barrier layer and thus the present invention broadly encompasses the use of environmental/thermal barrier layers on silicon containing substrates and on substrates having comparable thermal expansion coefficients.

According to the present invention, the silicon containing substrate may be a silicon containing ceramic substrate or a silicon containing metal alloy. In a preferred embodiment, the silicon containing substrate is a silicon containing ceramic material as, for example, silicon carbide, silicon nitride, silicon carbon nitride, silicon oxynitride and silicon aluminum oxynitride. In accordance with a particular embodiment of the present invention, the silicon containing ceramic substrate comprises a silicon containing matrix with reinforcing such as fibers, particles, and the like and, more particularly, a silicon based matrix which is fiber-reinforced. Particularly suitable ceramic substrates are a silicon carbide coated silicon carbide fiber-reinforced silicon carbide particle and silicon matrix, a carbon fiber-reinforced silicon